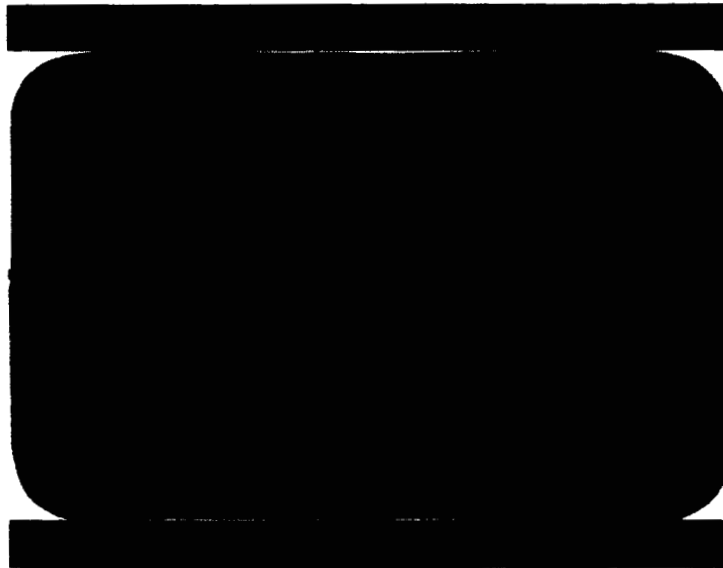


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GENERAL DYNAMICS
Convair Division



CORROSION RESISTANCE OF OUT-OF-CHEMISTRY
301 FULL HARD STAINLESS STEEL SHEET

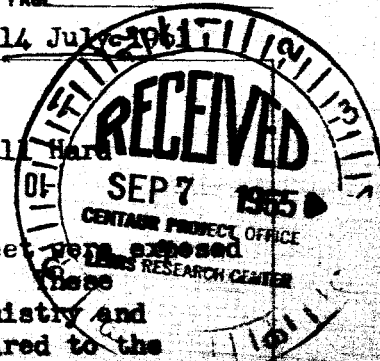
MRG-241

July 14, 1961

Prepared by: Charles J. Kropp

GENERAL DYNAMICS/CONVAIR

14 July 1961



SUBJECT: "Corrosion Resistance of Out-of-Chemistry 301 Full Hard Stainless Steel Sheet"

ABSTRACT: Four different heats of 301 stainless steel sheet were exposed to a combined stress and corrosion environment. These heats were chosen so as to include both in-chemistry and out-of-chemistry compositions of 301 when compared to the GD/A Specification 0-71004.

Samples of all four heats were fabricated into butt welded stress corrosion specimens using standard production welding techniques. Some were left in the as-welded condition and some had the weld joints roll planished. Welded and unwelded specimens of these heats were stressed to 80,000 psi by bending them into slotted fixtures and then placed in a salt spray cabinet for various lengths of time.

A metallographic examination was then conducted to determine the extent of corrosion attack and its relation to the chemistry of the materials.

No correlation between the chemistry and corrosion attack could be made. The corrosion attack on all specimens tested was negligible. Control specimens of the same heats which were not exposed to salt spray corrosion tests contained microscopic surface scratches or irregularities. The depths of these surface irregularities are larger in some cases than the irregularities found in the specimens subjected to the salt spray, for example 0.00006" to 0.00024" in depth.

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14 July 1961

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14 July 1961

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SUBJECT: Corrosion Resistance of Out-of-Chemistry 301 Full Hard
Stainless Steel Sheet.

BACKGROUND:

At the request of the Project Office an investigation was started to determine the effect of stress corrosion environments on out-of-chemistry heats of 301 full hard stainless steel sheet which were purchased to General Dynamics/Astronautics Specification 0-71004.

MATERIAL TESTED:

Four heats of 301 full hard stainless steel sheet were obtained from current stock. Of these heats one is in-chemistry and the remaining three heats are out-of-chemistry when compared with the General Dynamics/Astronautics Specification 0-71004. Heat number 157104 represents the in-chemistry heat. Heat number 32786 is low in chromium by 0.8 percent. Heat numbers J48562 and J48646 are both high in carbon content by 0.1 percent. In addition heat number J48562 is low in chromium by 0.2 percent and heat number J48646 is low in chromium by 0.3 percent.

TEST PROCEDURE:

Strips of all four heats were butt welded by Department 758 using standard production techniques. Half of all these welded strips were also roll-planished by Department 758 and the remainder were left in the as-welded condition. Approximately one inch wide corrosion test specimens were cut from the strips so that the welds were longitudinal with respect to the major axis of the specimens.

The specimens were stressed to 80,000 psi tensile stress (50% of yield stress required in Specification 0-71004) by flexing and snapping the specimens into slots cut in blocks of micarta. The specimen lengths and the distance between the slots cut into the micarta block were calculated by using the curves shown in Figure 1. Specimen lengths (see Figure 2) were calculated to obtain the desired tensile stress when the specimens were placed into the corrosion fixtures shown in Figure 3. A value of 26×10^6 psi was used for Young's Modulus in these calculations. This value was obtained from MIL-HDBK-5, March 1959.

Nine specimens of each heat in the unwelded, the welded and roll-planished,

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and the as-welded conditions were bent into the slots in the micarta blocks and placed in a salt spray cabinet. This cabinet meets the specifications listed in Method 811 of the Federal Test Method Standard No. 151, 17 July 1956. A twenty percent solution of sodium chloride in water was used in the cabinet.

All specimens were exposed to the salt spray for periods of 36, 72, and 168 hours. Since triplicate specimens were placed in the salt spray cabinet, it was possible to remove specimens of each heat and of each condition after the exposure times indicated above.

After each period of exposure, a group of specimens was removed from the cabinet and examined on the surfaces for corrosion pits with particular attention given to the heat affected zones of the welded specimens. The heat affected zones are more susceptible to corrosion effects because the temperature incurred during welding causes a reaction between the chromium and carbon content in the steel to form chromium carbides. This reaction due to welding depletes the surrounding material of chromium, thus the material is less corrosion resistant than it is in the unwelded condition. The 301 specification (Q-71004) limits the carbon content to a maximum of 0.10 percent which limits the degree of carbide formation which can occur.

After the surfaces of all specimens were examined and the degree of surface corrosion attack was recorded, the specimens were cross-sectioned and prepared for metallographic examination. These specimens were sectioned transversely so that the degree of corrosion could be examined at the location of maximum tensile stress due to bending, and base metal, weld metal, and heat-affected zones could be examined.

The specimens were all etched electrolytically for five minutes in a ten percent solution of sodium cyanide in water. This etchant is capable of darkening any carbide precipitation network present in a stainless steel without affecting the austenitic matrix of the stainless steel.

DISCUSSION AND RESULTS:

After the metallographic examination of all the corrosion specimens was completed, the results were studied in an attempt to correlate the effects of the combined stress and corrosion environment on 301 stainless steel sheet which were out-of-chemistry to the degree shown in Table 1. The corrosion attack was negligible in all the specimens tested. No correlation could be made of the degree of corrosion attack in the carbide precipitation zone of the welded specimens when compared to the chemistry of the materials.

Control specimens of each heat which were not subjected to the salt spray were also compared to the specimens exposed to the salt spray. The control specimens contained surface irregularities which were 0.00006" to 0.00024"

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deep. These surface defects are presumably scratches resulting from the abrasive grinding of the surfaces of the steel sheet at the mill to remove surface flaws.

Previous metallographic examination of 0.010" thick 301 half hard material used in the fabrication of stretched-formed gore skins at GD/A indicated that this material also contained surface scratches which were 0.00006" deep. Another heat of 301 (0.0185" thick) which was also formed into gore skins for bulkheads contained surface scratches which ranged from 0.0003" to 0.0006" deep. The above work was performed on unwelded material.

The results of observed pitting as shown in Table 2 may then indeed contain the measurement of surface scratches (present before salt spray exposure) as well as the measurement of any minute pitting due to the combined stress and corrosion exposure. These two types of surface defects could not be differentiated, however, the surface irregularities measured after the 168 hour salt spray exposure were no more severe and in one case (See Figure 8) less than the surface irregularities present in the control specimens (see Figures 4 through 9). These photomicrographs represent the worst area of surface irregularities of each heat of material.

From the results obtained from these tests it can be seen that even after a severe salt spray exposure of 168 hours, out-of-chemistry 301 stainless steel under a stress of 80,000 psi does not show evidence of pitting or cracking in the carbide precipitation area of welded specimens to a degree greater than the surface defects found in samples of the same heats which were never exposed to the salt spray corrosion test.

Table 1. Chemical Analysis of 301 Stainless Steel

Thickness, In.	Heat No.	(1) Heat No.	Coil No.	Element, %							Remarks
				C	Mn	P	S	Cr	NI	SI	
Nominal	Actual										
0.013	0.013	157104	453	0.10	0.55	0.026	0.010	17.0	6.88	0.62	In-Chemistry Heat
0.010	0.0095	32786	43100 ⁽²⁾	0.096	0.88	0.024	0.018	16.2	7.17	0.52	Low Cr
			43101								
0.010	0.0095	J48562	44372	0.11	0.62	0.020	0.027	16.8	7.13	0.41	High C, Low Cr
0.019	0.0185	J48646	450	0.11	0.55	0.020	0.022	16.7	7.28	0.52	High C, Low Cr
CD/A Specification No. 0-71004				0.10	2.0	0.04	0.03	17.0	6.5	1.0	
(maximum amounts except as noted)								Min.	Min.		

1. Washington Steel Company Heat Numbers
2. One end of this coil was marked 43100 while the other end was marked 43101.

Table 2- Results of the Stress Corrosion Tests of Seam Butt Welded 301

<u>Salt Spray Exposure Time</u>	<u>Degree of Pitting or Surface Irregularities</u>		
	<u>Worst</u>	<u>Intermediate</u>	<u>Least</u>
No exposure (control samples) surface pitting due to scratches during rolling	0.00010" to 0.00024" deep, Heat Nos. J48562 and J48646	-	0.00006" to 0.00008" deep Heat Nos. 32786 and 157104
	0.00016" deep Heat No. J48562	0.00006" deep Heat No. J48646	0.00004" deep Heat Nos. 32786 and 157104
	0.00008" deep Heat No. J48646	0.0006" deep Heat Nos. J48562 and 32786	0.00004" deep Heat No. 157104
36 Hours	0.0001" to 0.00012" deep Heat Nos. J48562 and 157104	-	0.00006" to 0.0001" deep Heat Nos. J48646 and 32786
72 Hours			
168 Hours			

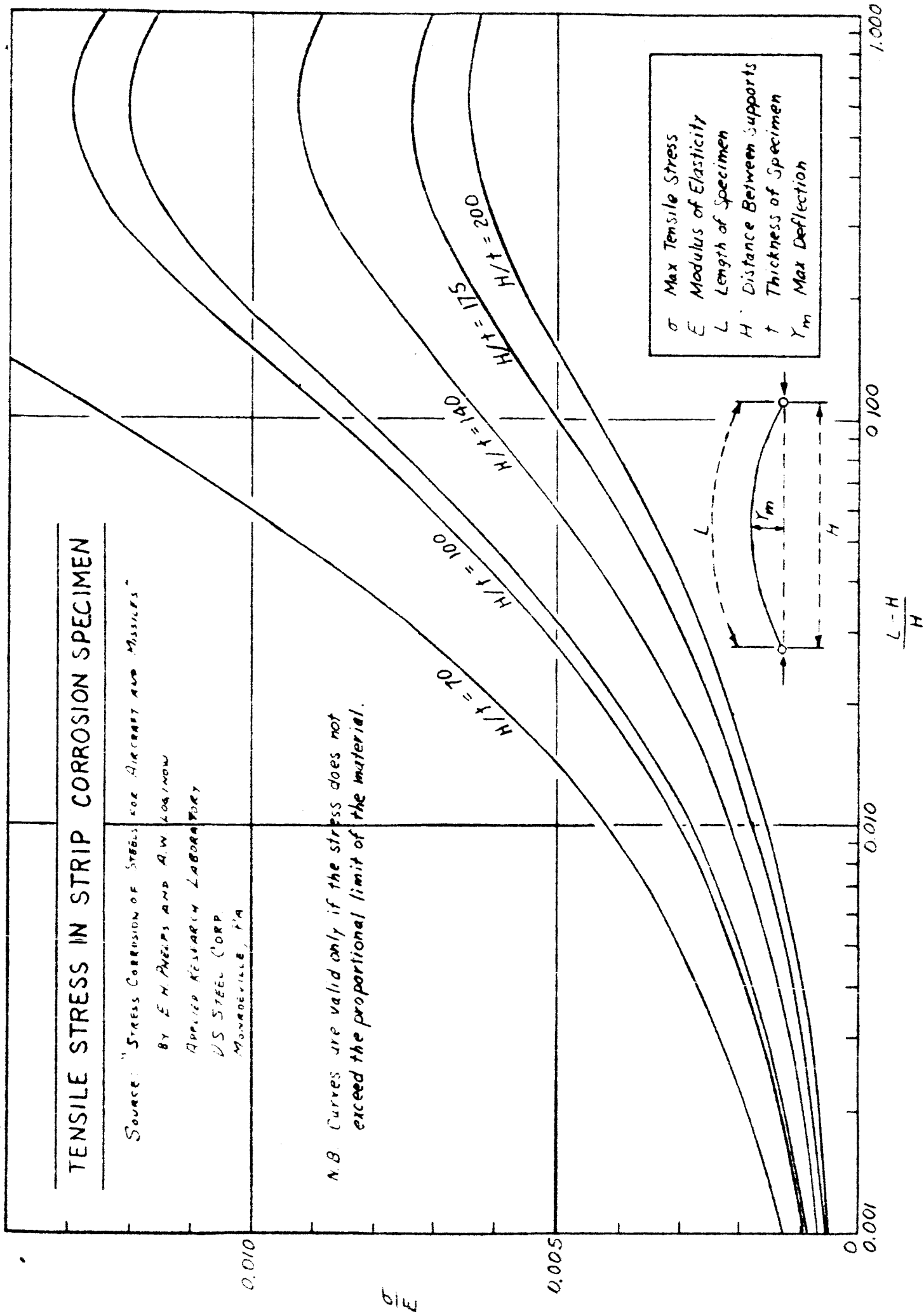
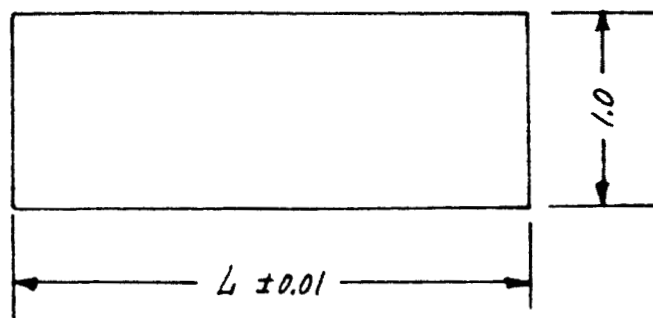
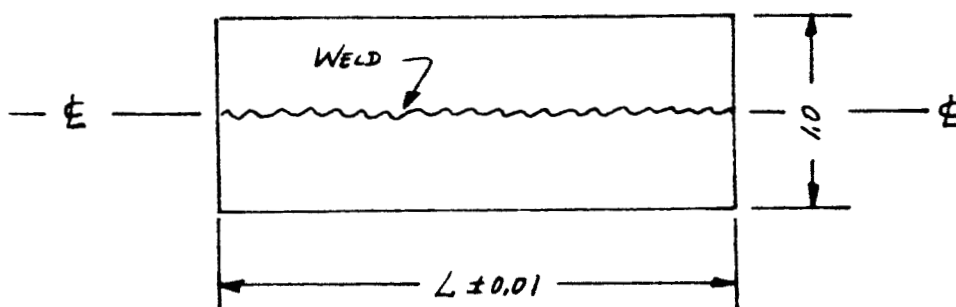


Figure 1. Curve for the Calculation of Stress Corrosion Specimen Lengths

FIG. 2. STRESS CORROSION SPECIMENS



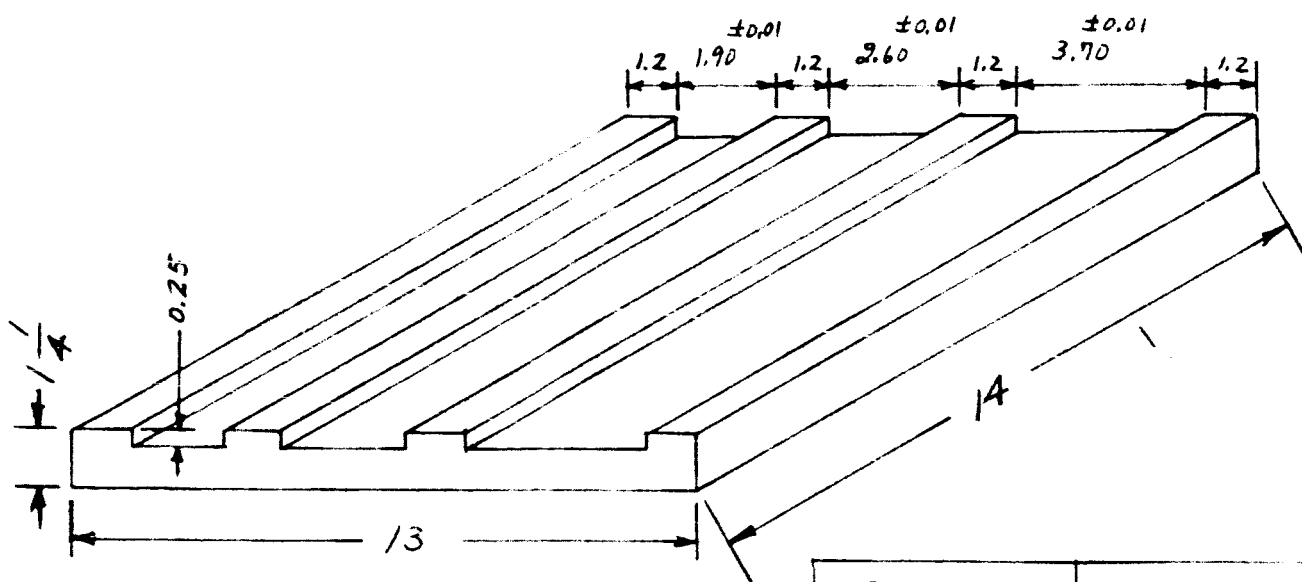
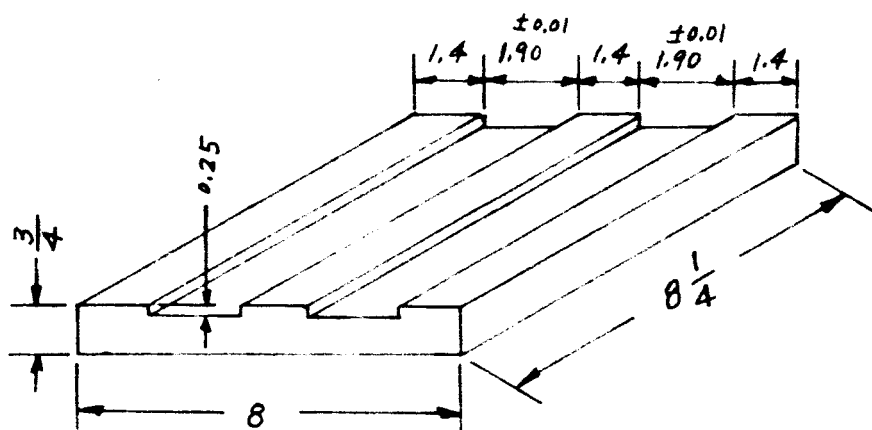
UNWELDED STRESS CORROSION SPECIMEN



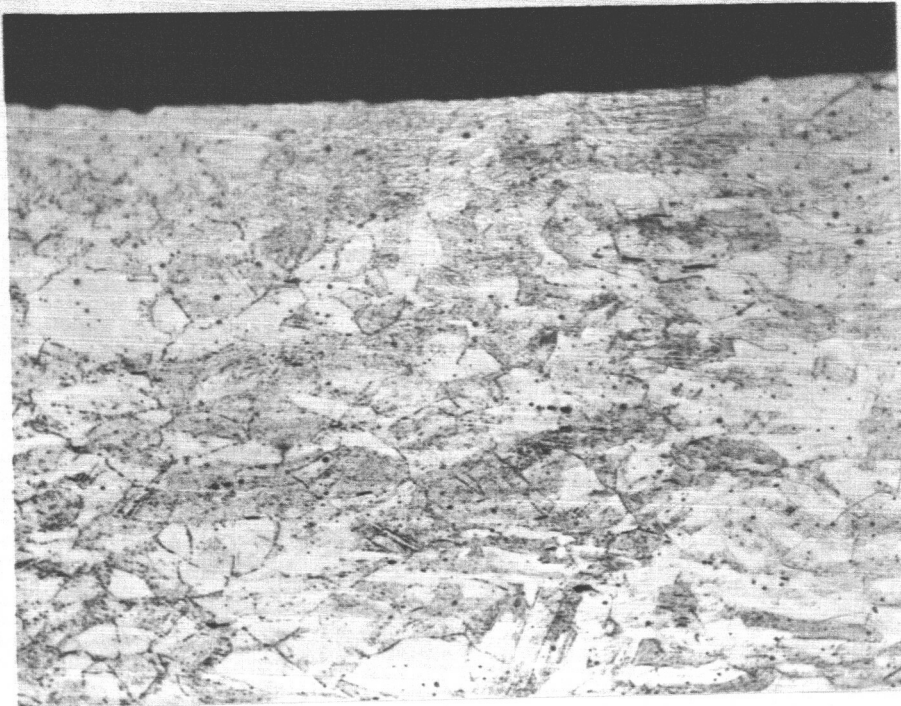
SEAM BUTT WELDED STRESS CORROSION SPECIMEN

THICKNESS, IN.	LENGTH (L), IN. FROM FIG. 1.
0.010	1.99
0.013	2.72
0.019	3.87

FIG. 3. STRESS CORROSION FIXTURES



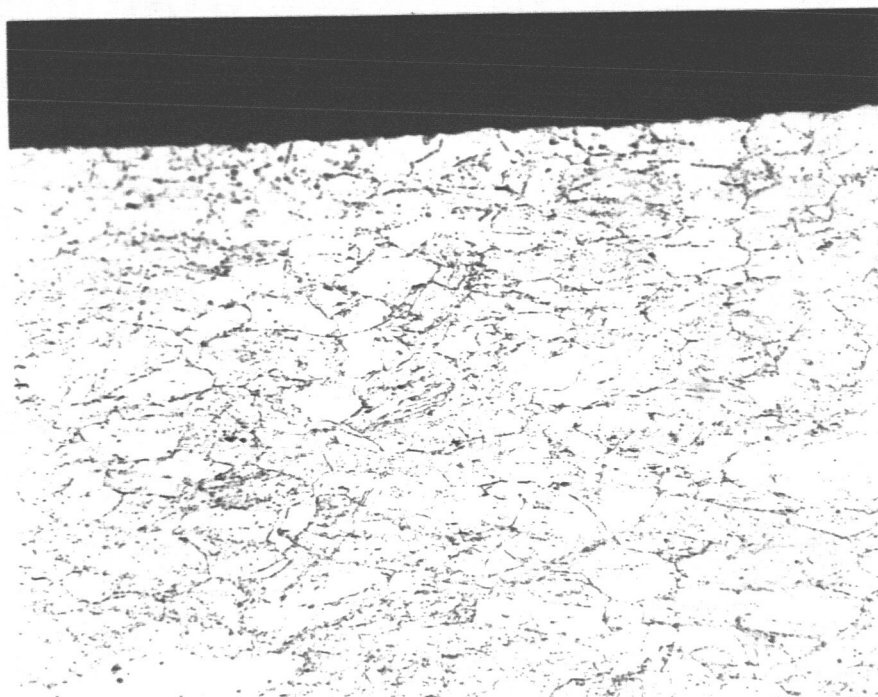
SPECIMEN THICKNESS, IN.	DISTANCE BETWEEN SUPPORTS, H , FROM FIG. 1.
0.012	1.90
0.013	2.60
0.014	3.70



500X

Etchant: Electrolytic
Sodium Cyanide,
5 Min.

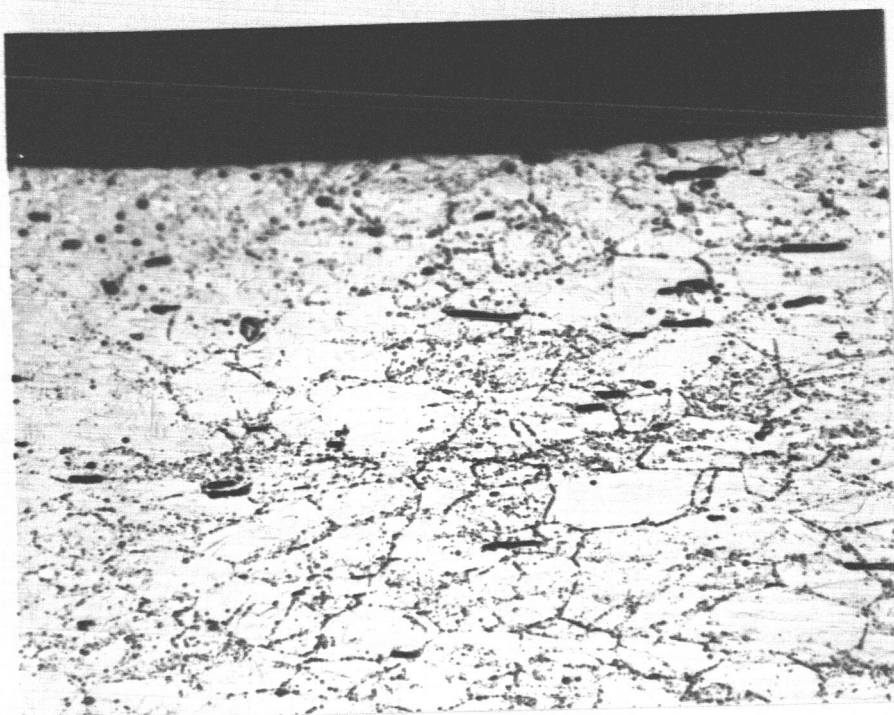
Figure 4. Heat affected zone of 301 stainless steel with no salt spray exposure. Heat No. 157104. The largest surface irregularity is 0.00008" deep.



500X

Etchant: Same as Above

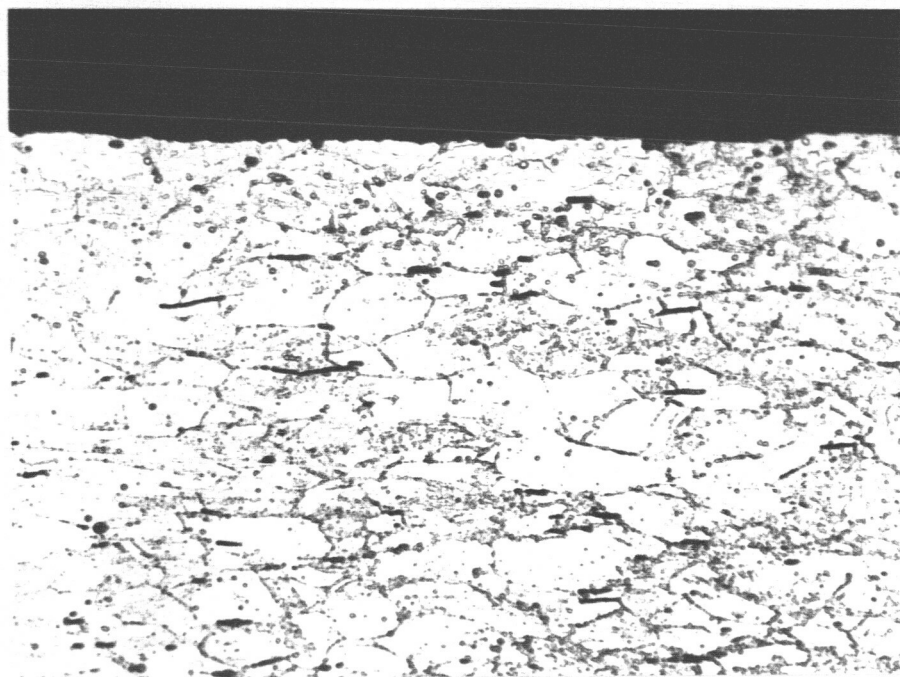
Figure 5. Same as above except the sample was exposed to the salt spray for 168 hours while being stressed at 80,000 psi. The largest surface irregularity is 0.00008" deep.



500X

Etchant: Same as in Figure 4.

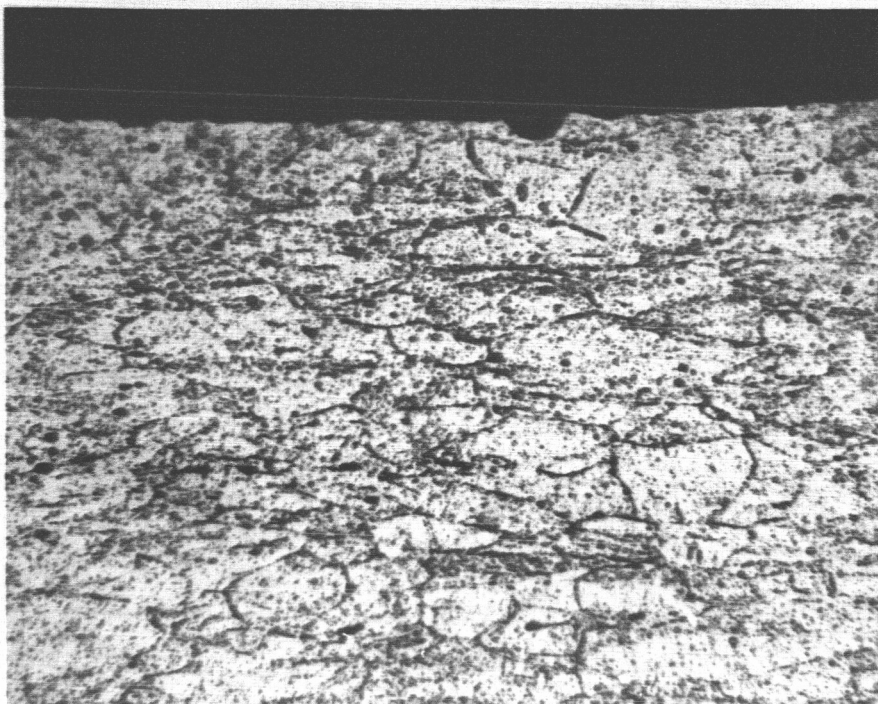
Figure 6. Heat affected zone of 301 stainless steel with no salt spray exposure. Heat No. J48562. The largest surface irregularity is 0.00012" deep.



500X

Etchant: Same as in Figure 4

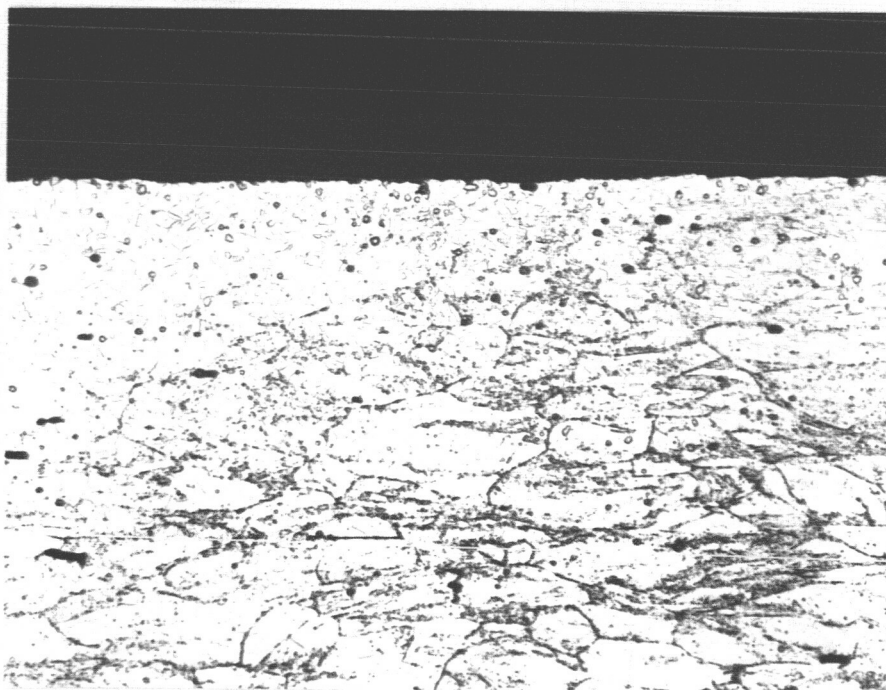
Figure 7. Same as above except the sample was exposed to the salt spray for 168 hours while being stressed at 80,000 psi. The largest surface irregularity is 0.00012" deep.



500X

Etchant: Same as in Figure 4.

Figure 8. Heat affected zone of 301 stainless steel with no salt spray exposure. Heat No. J48646. The largest surface irregularity is 0.00024" deep.



500X

Etchant: Same as in Figure 4.

Figure 9. Same as above except the sample was exposed to the salt spray for 168 hours while being stressed at 80,000 psi. The largest surface irregularity is 0.0001" deep.

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